CONTROLLING AUTOMOTIVE TEST RIGS

A review of industrial control methods for dynamic vehicle and component testing in the laboratory

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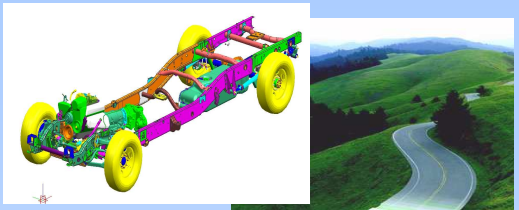
Introduction

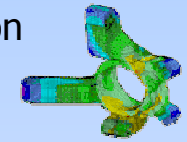
- The dynamic testing of vehicle structures and components in the laboratory to determine their mechanical properties (dynamic characteristics, durability etc.) is an essential part of automotive R&D.
- Test apparatus designed to replicate real-world forces and motions requires accurate control of actuators.
- Algorithms which are currently used in the testing industry, both new and well established, are reviewed.
- As both the required forces and frequency range are often high, electrohydraulic actuation is typically used.

Automotive testing in the laboratory

- suspension and axle durability testing and characterisation
- tyre and wheel testing
- steering testing
- crash testing to assess occupant safety systems
- pedestrian impact testing
- exhaust system durability testing
- seat, dashboard, and trim vibration testing
- engine and driveline characterisation
- full vehicle testing – characterisation for ride, handling and durability

Track testing



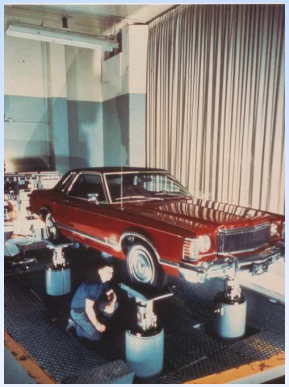


Simulation

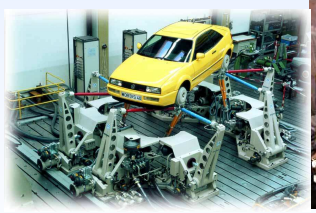
Lab testing

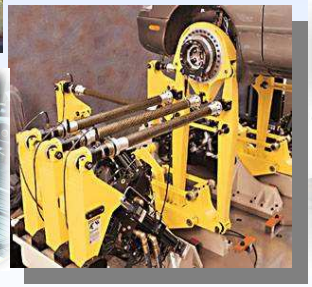
Servohydraulics

Analogue control



Digital control and multi-axis systems





1960s | 1970s | 1980s | 1990s | 2000 -

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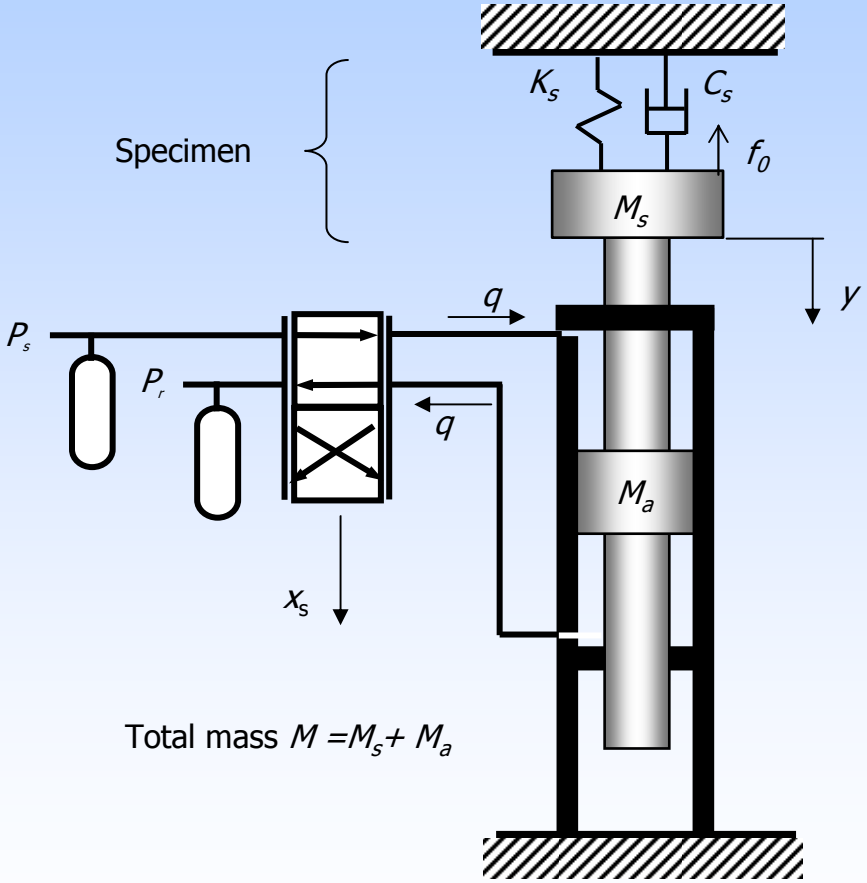
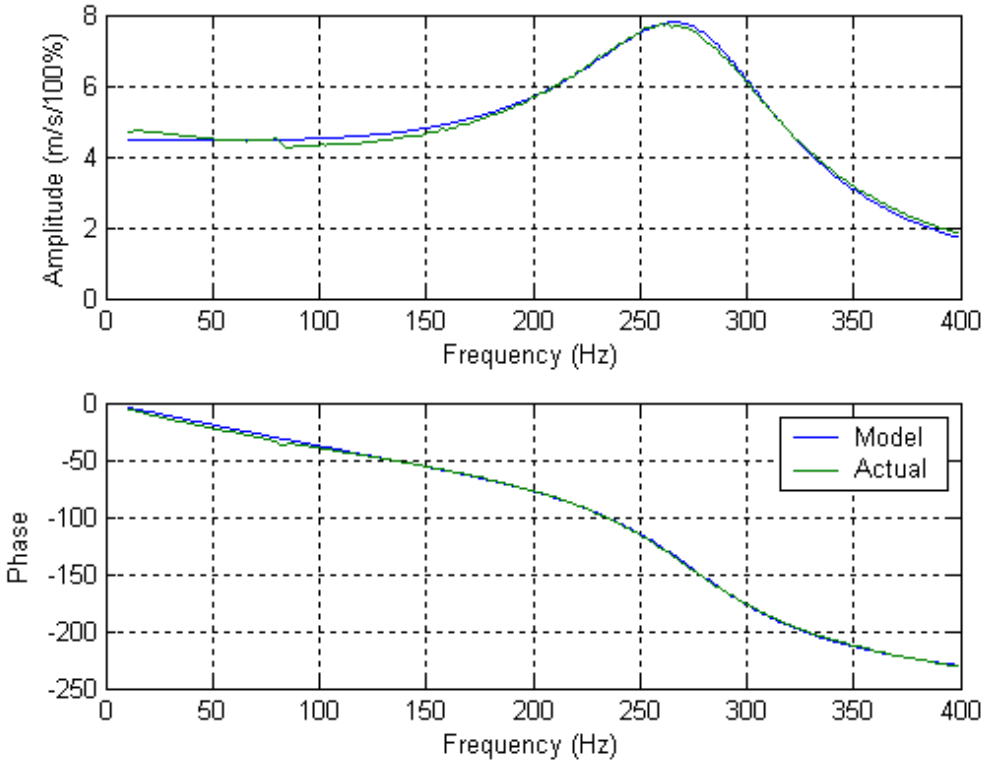
Contents

- Proportional Integral control
- High performance single axis control
- Iterative control
- Non-linear iterative control example
- Multi-axis control
  - Motion-compensated load control
  - Co-ordinate transformation
- Model-in-the-loop testing

Example actuator response





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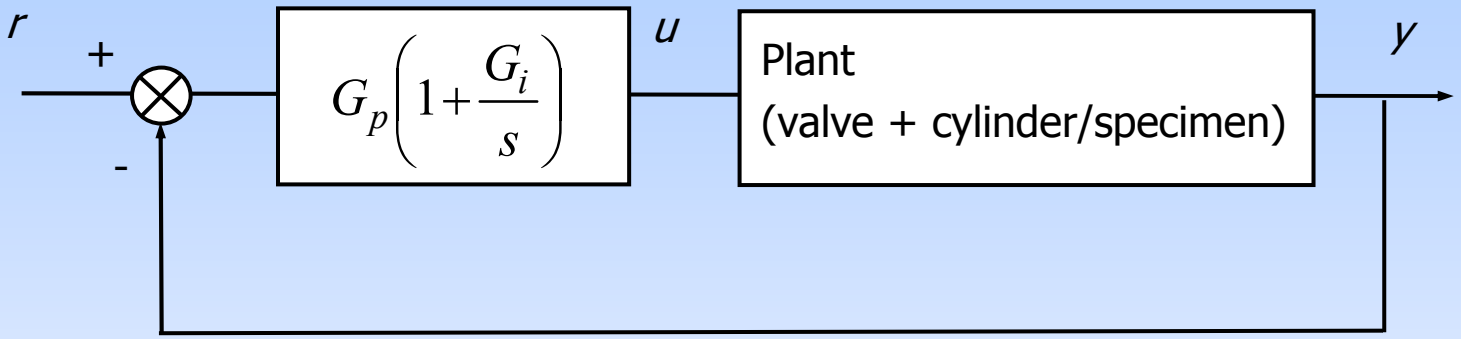
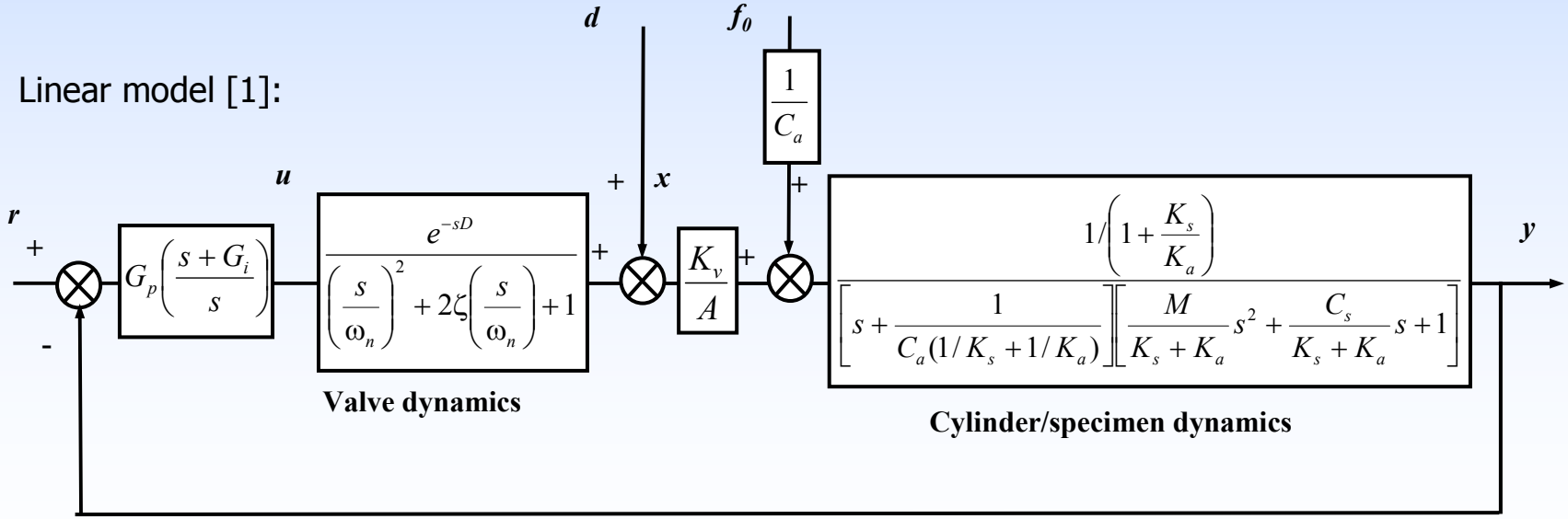
Proportional + Integral (PI) controller



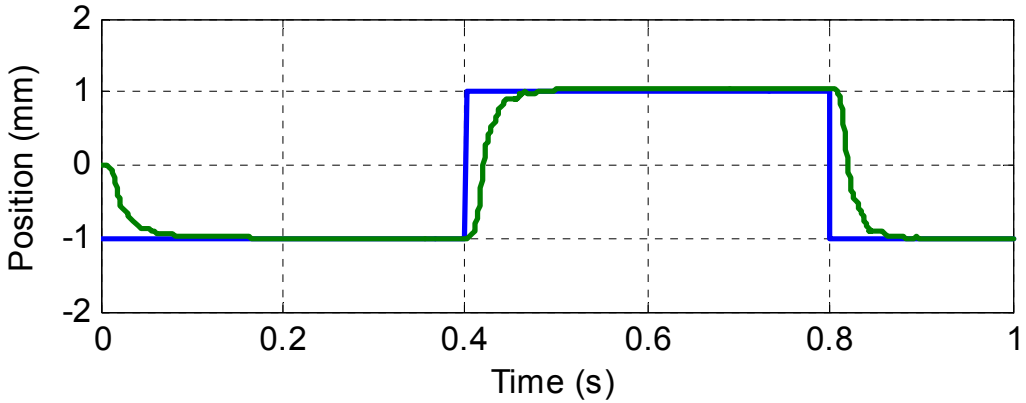
Linear model [1]:

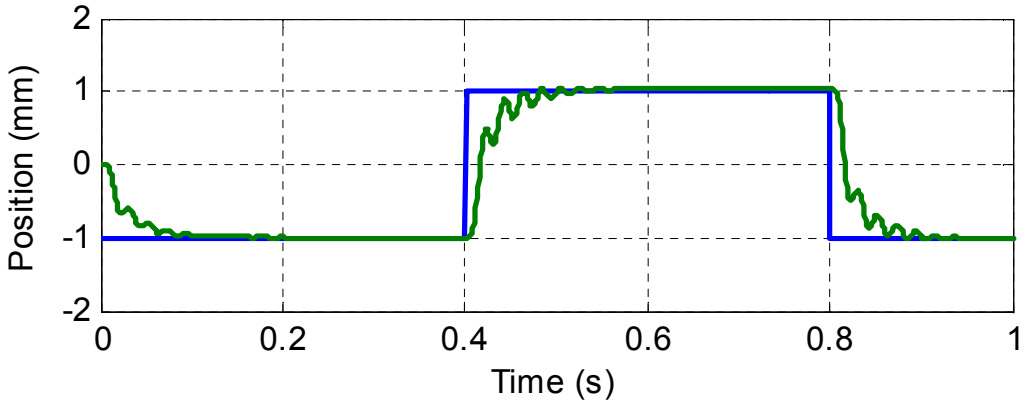


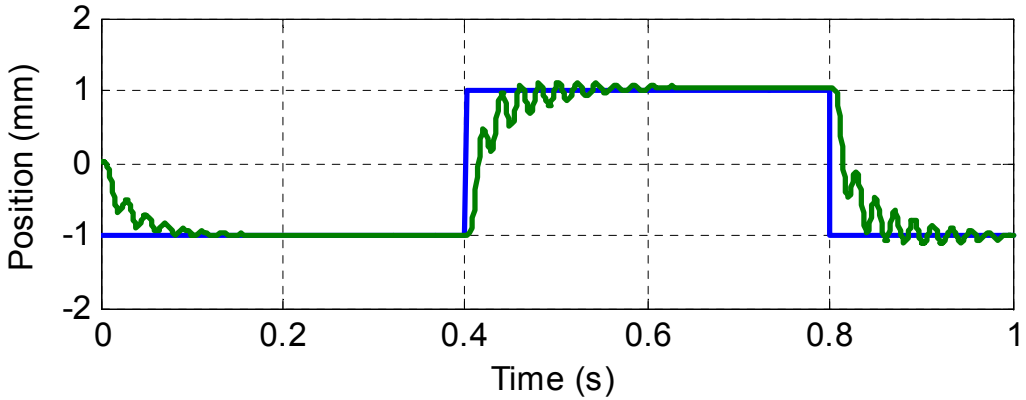
Hydraulic resonance

e.g. 50Hz hydraulic resonance

Valve bandwidths of:
50Hz
100Hz
200Hz







Resonance compensation:

- acceleration feedback
- differential pressure or load feedback
- a first order lag
- a notch filter
- A cross-port bleed

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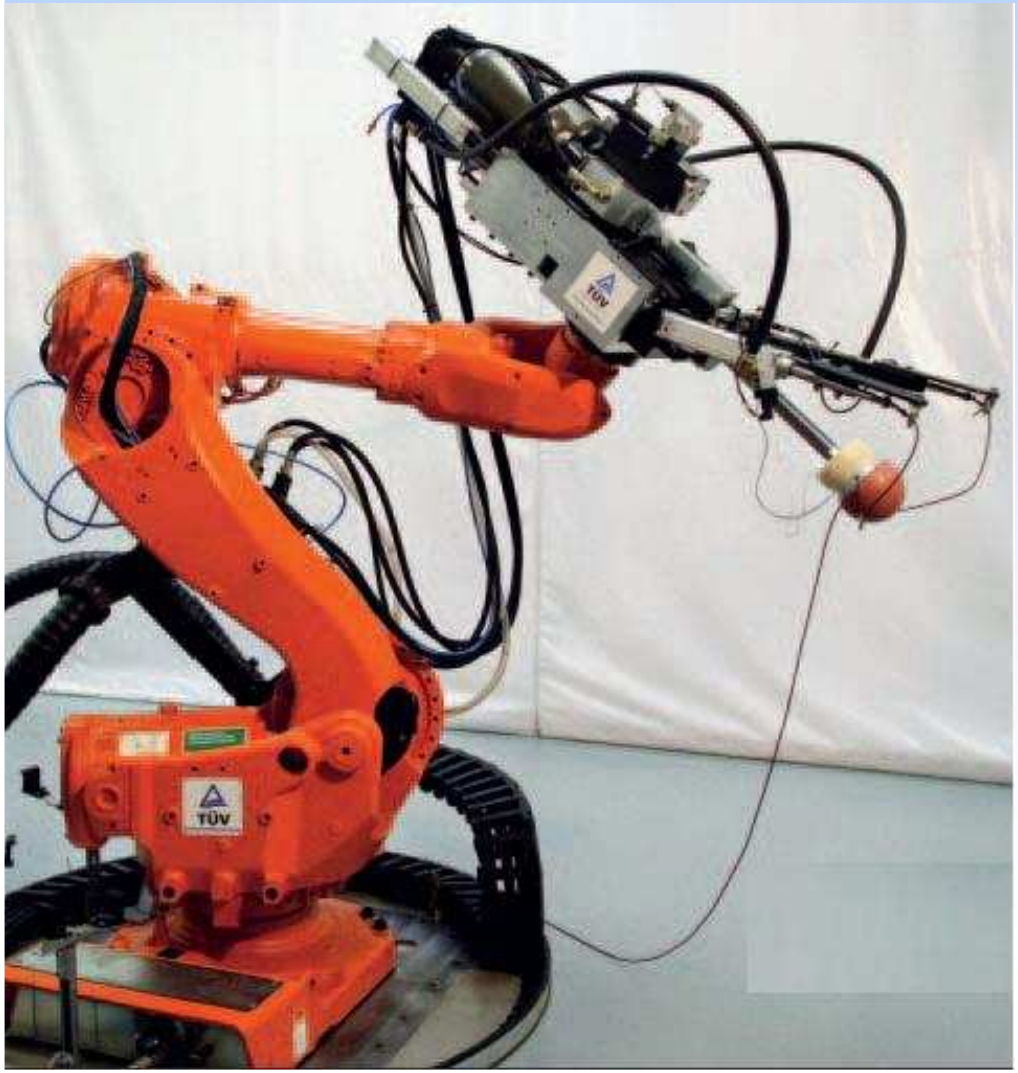
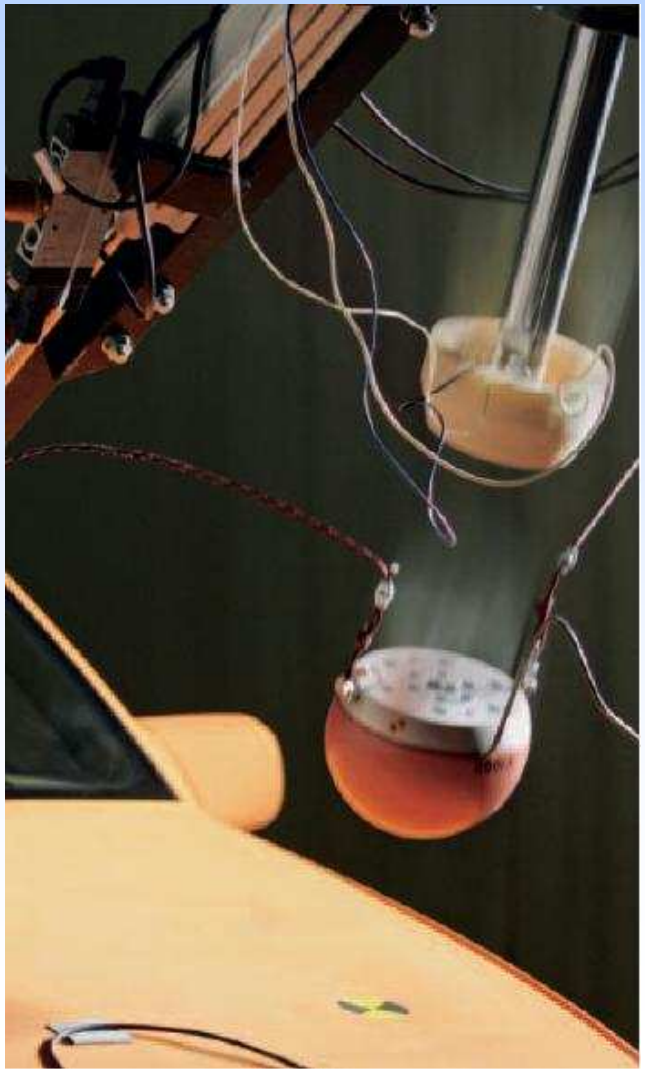
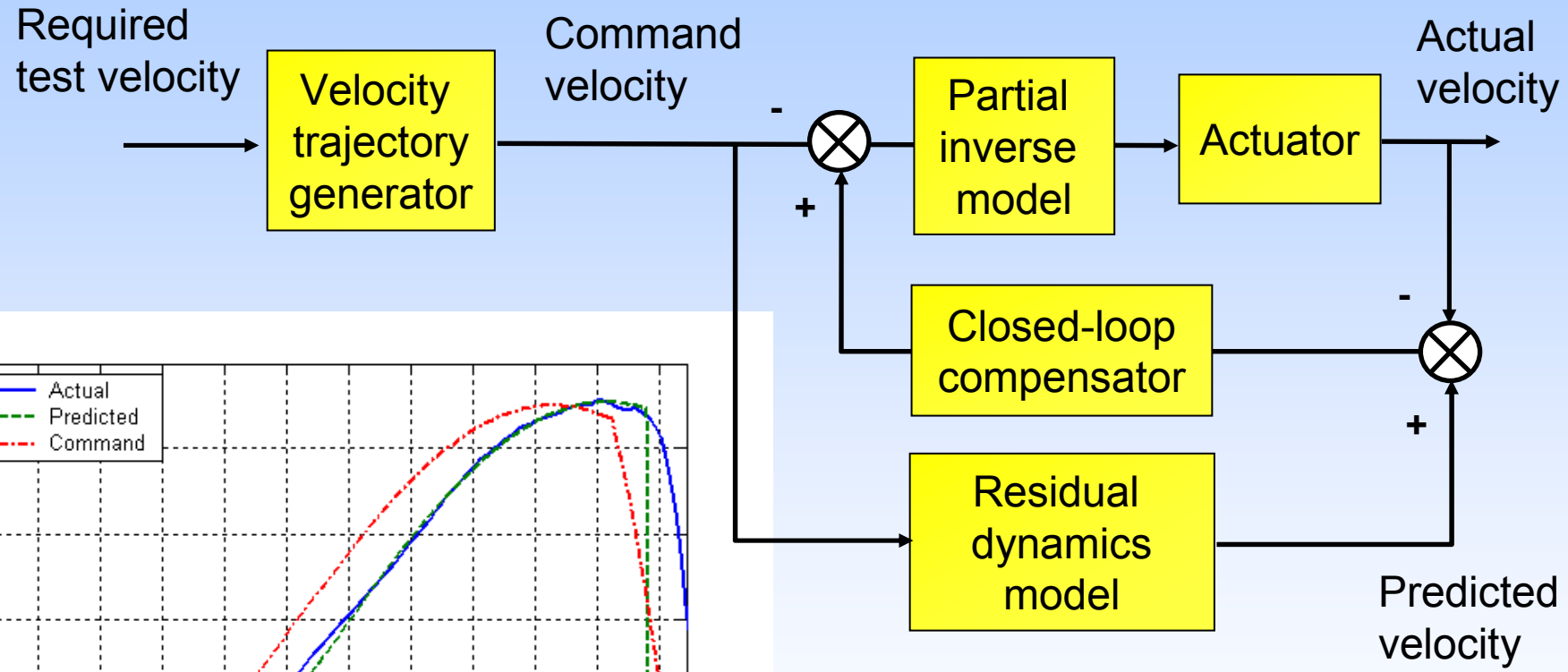
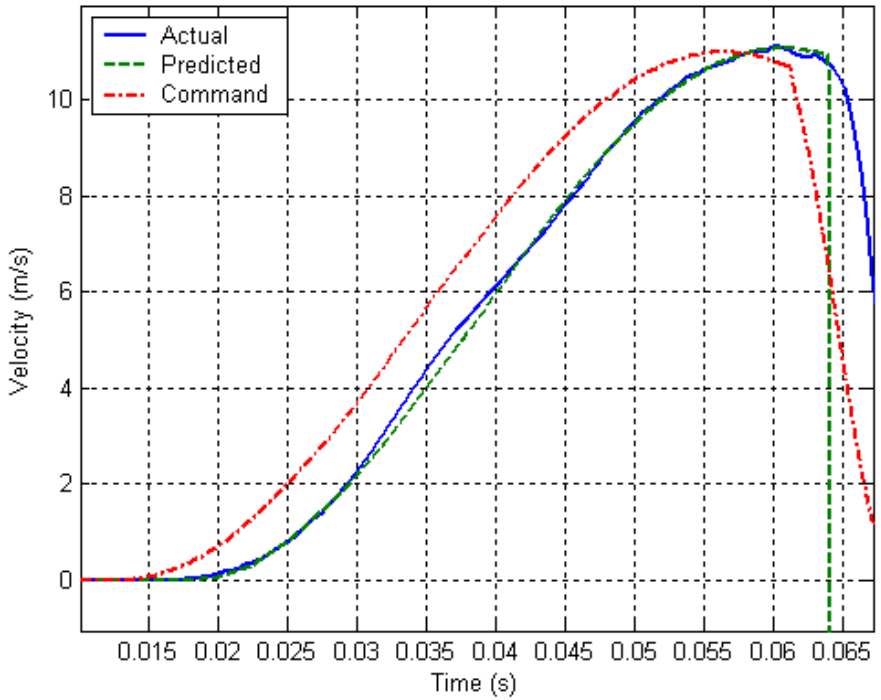
High performance single-axis control e.g. pedestrian impact testing





New non-linear model-based closed-loop controller [2]





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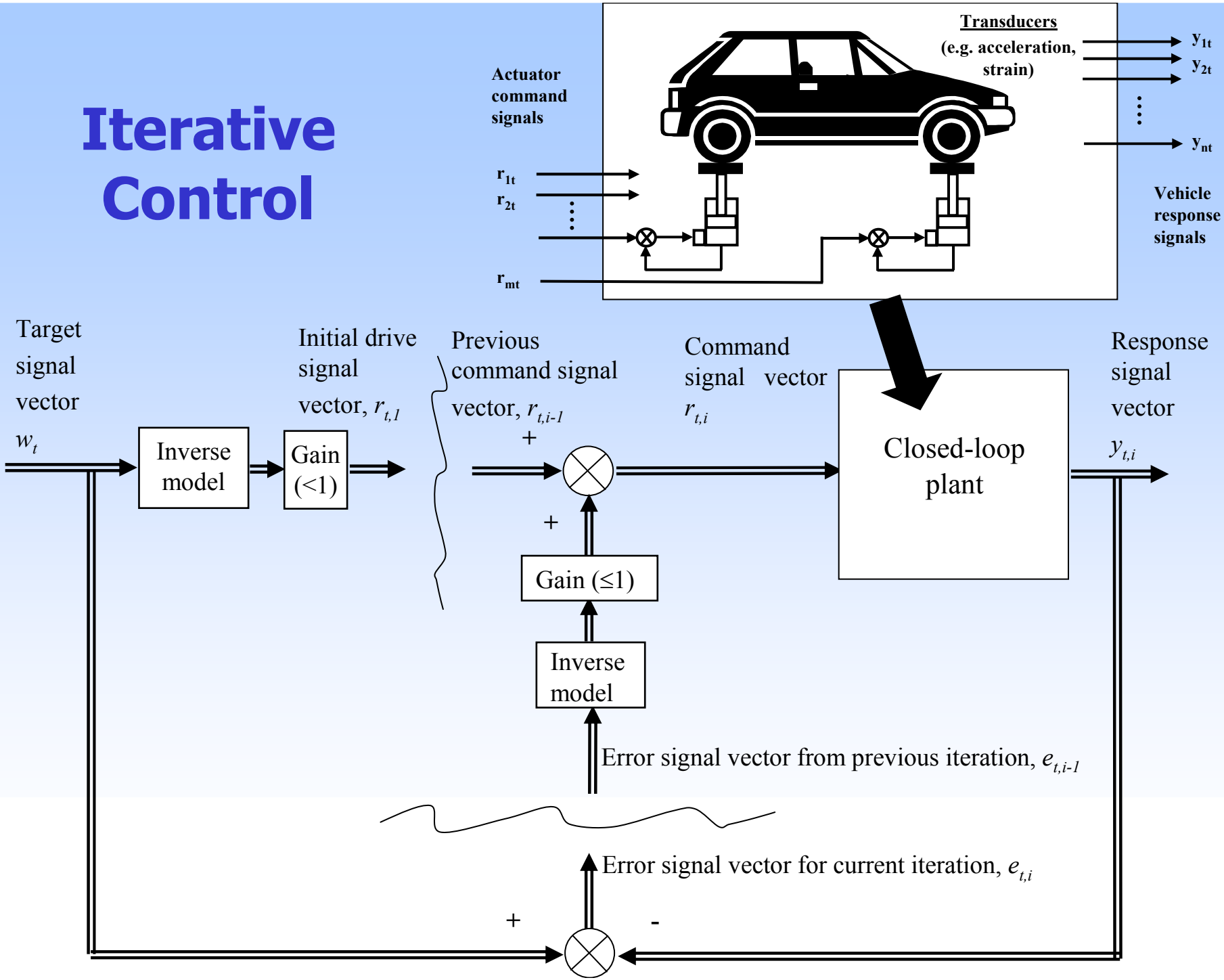
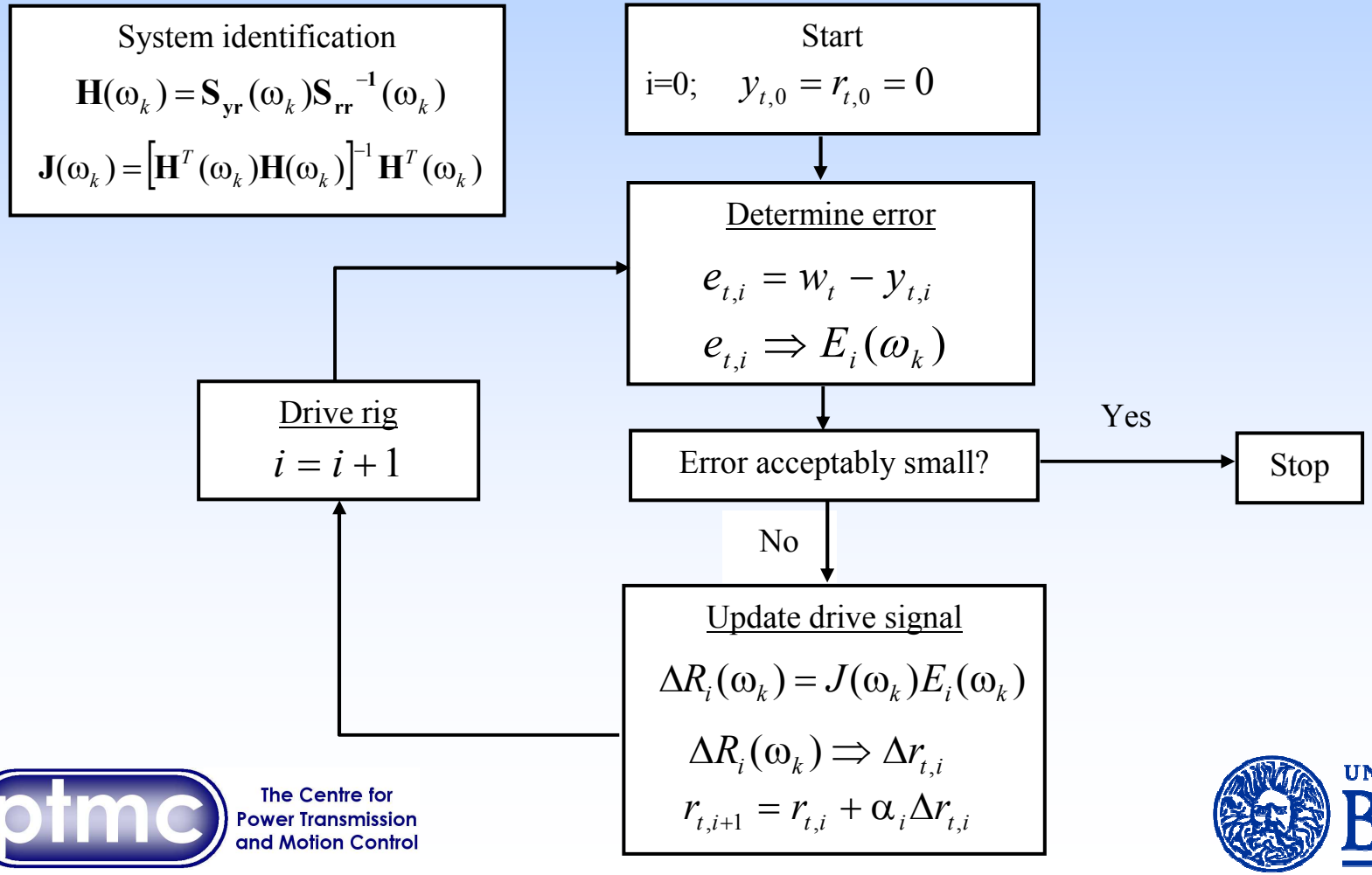
Iterative Control



Frequency domain iteration

- First used for 4-post testing in 1976 [3]



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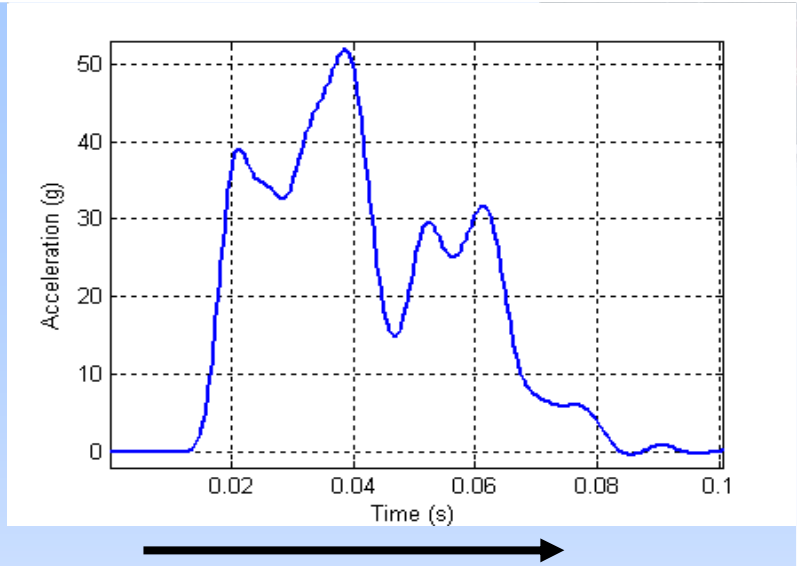
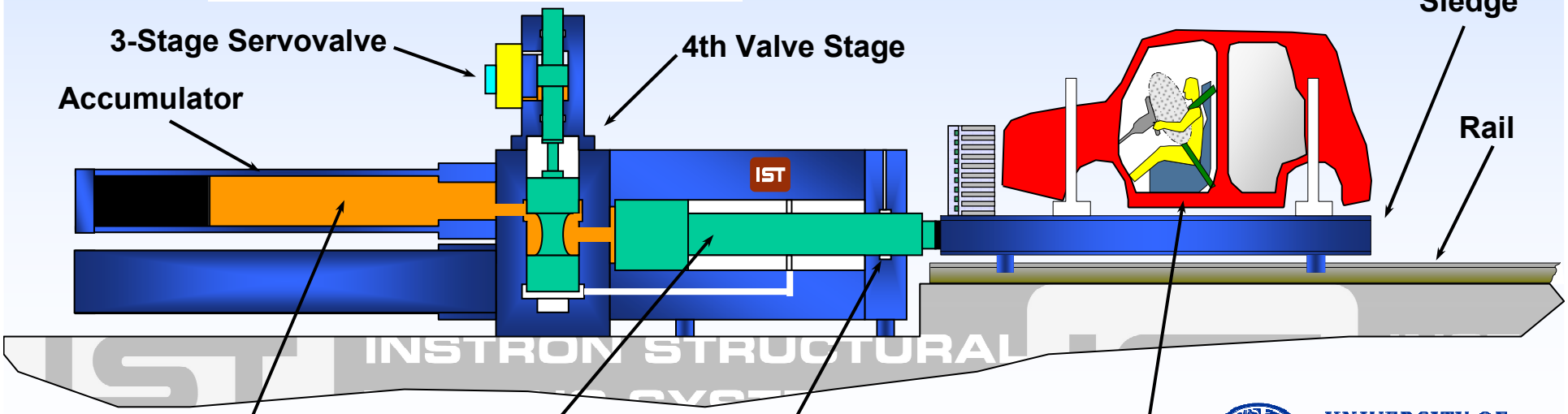
Non-linear iterative control

e.g. hydraulic catapult for occupant restraint testing [4]





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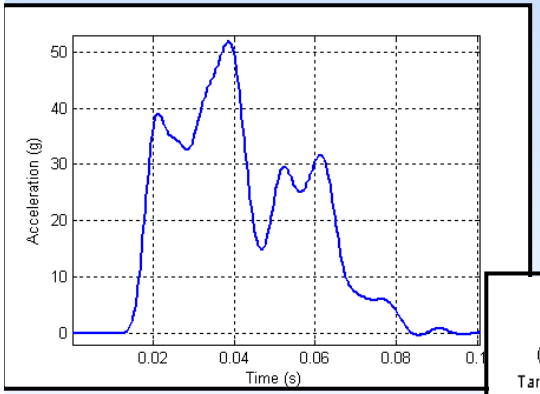
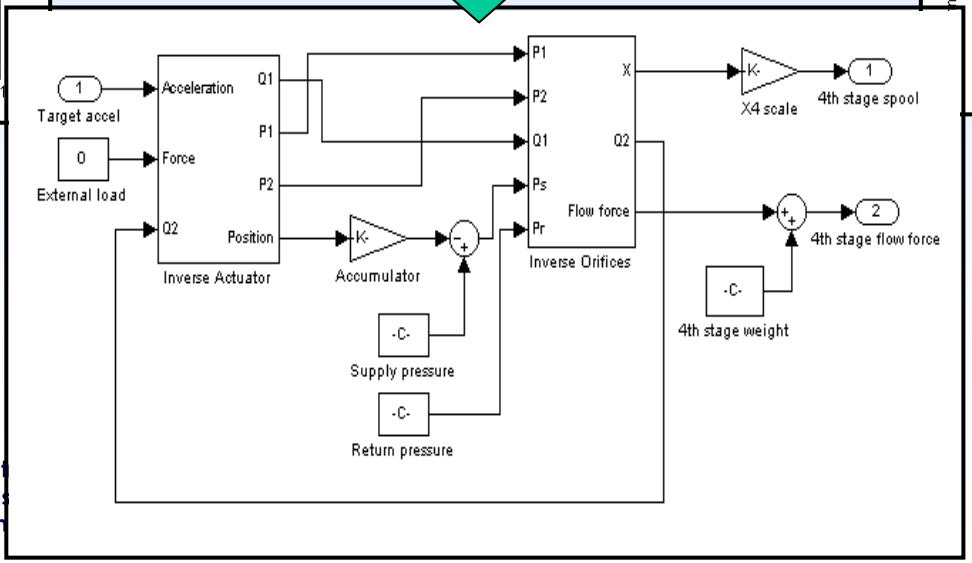
Calculating command signal

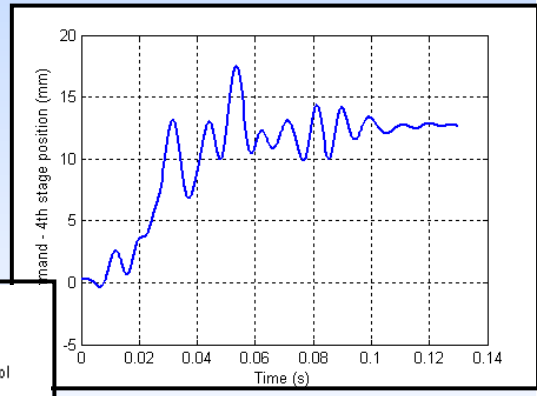
Target acceleration

Inverse Dynamic Model

Valve command signal







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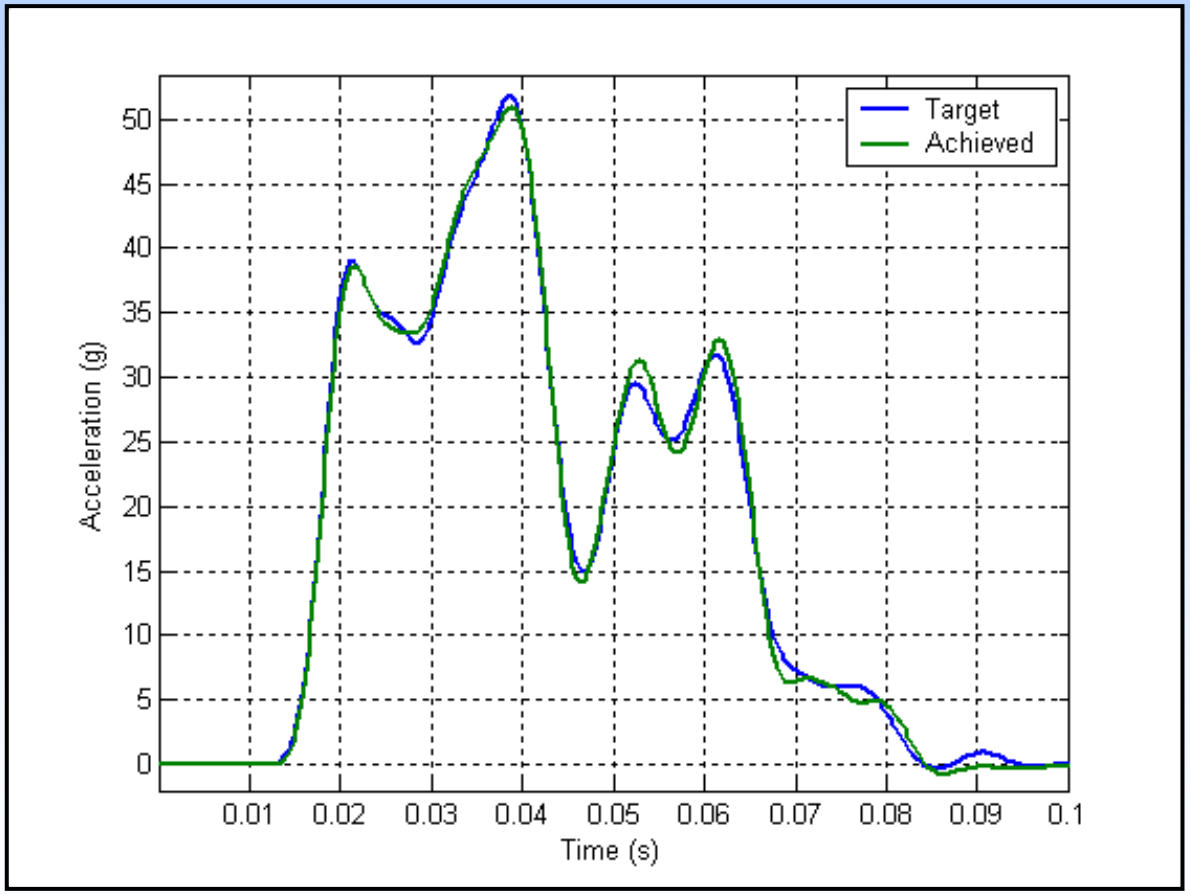
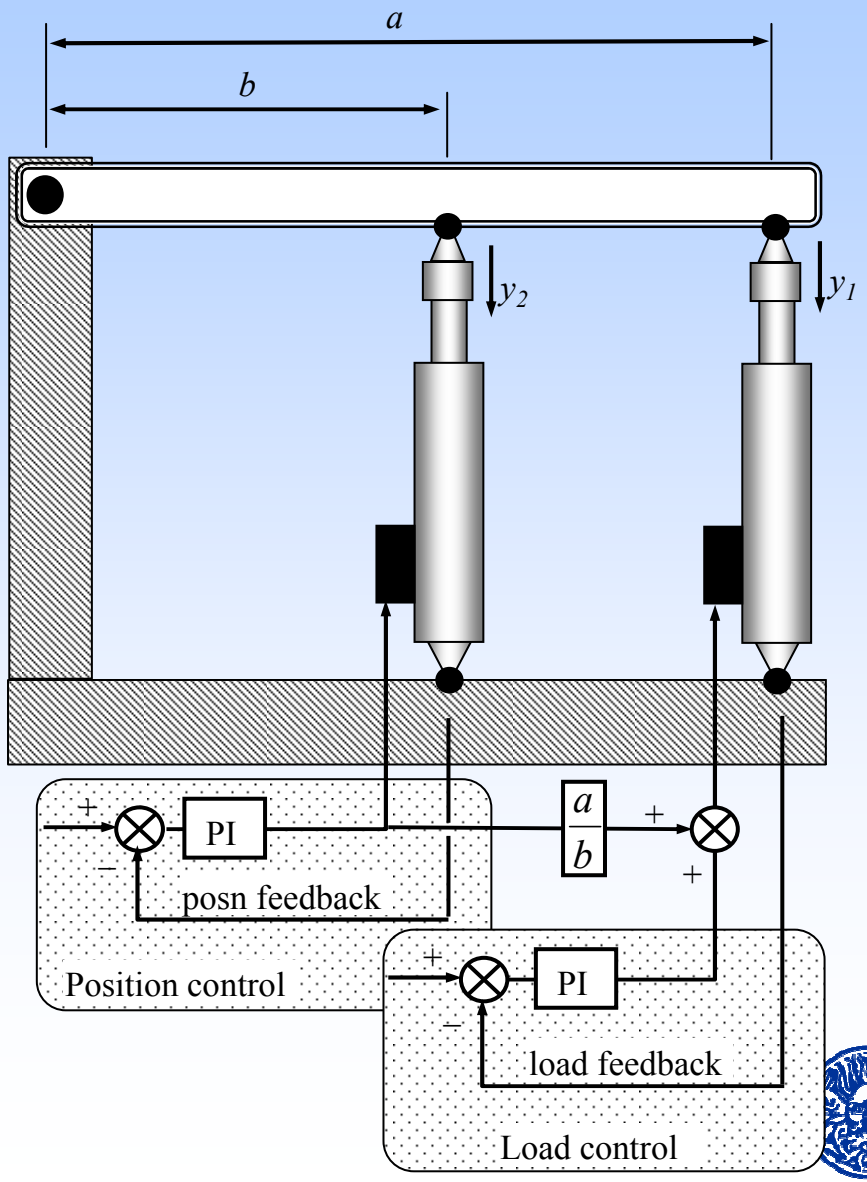
Results


Target
Achieved
Acceleration (g)
Time (s)
0
5
10
15
20
25
30
35
40
45
50
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1

Motion compensated load control

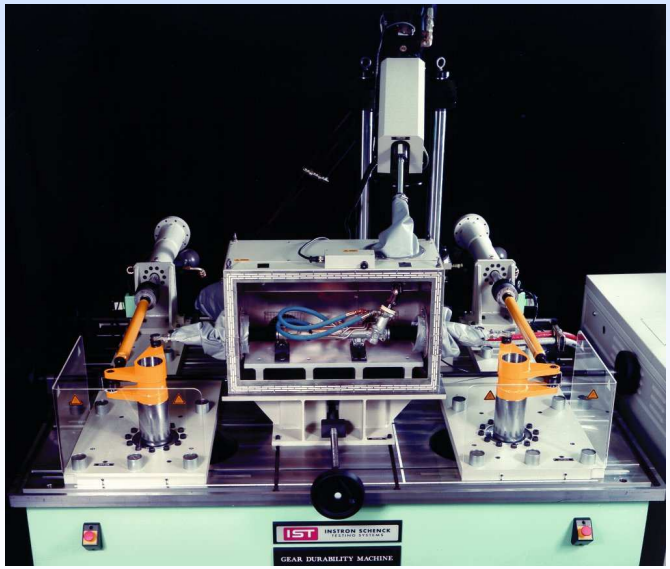
Valve cross-compensation

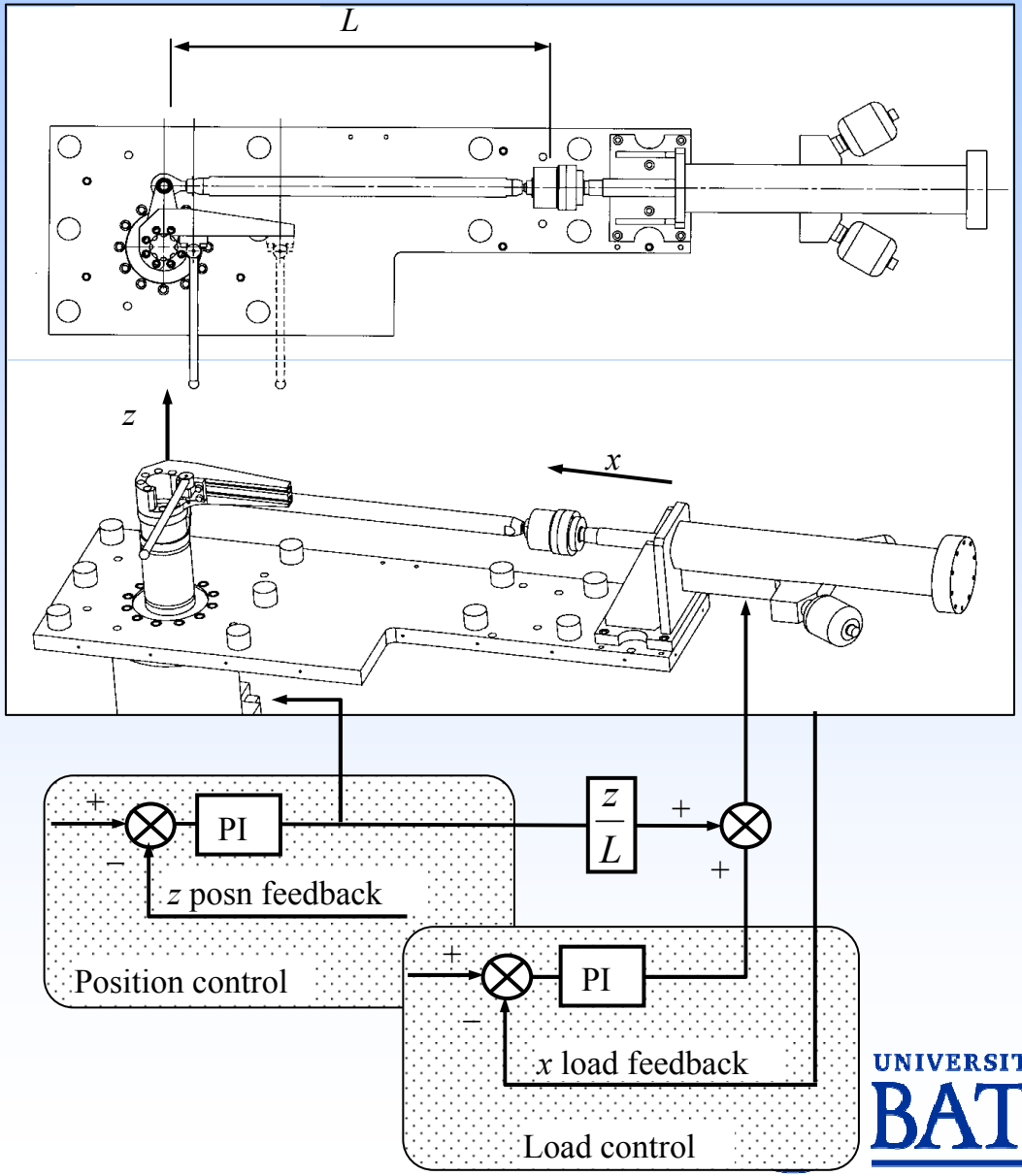


Motion compensated load control

Variable valve cross-compensation

e.g. steering test rig





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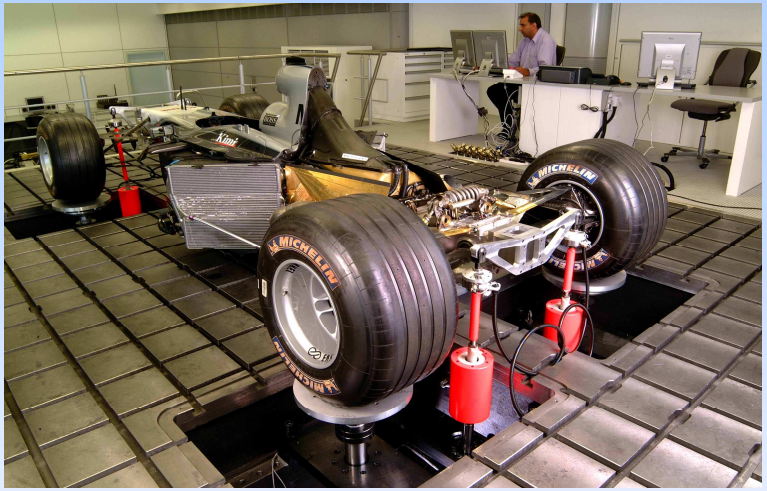
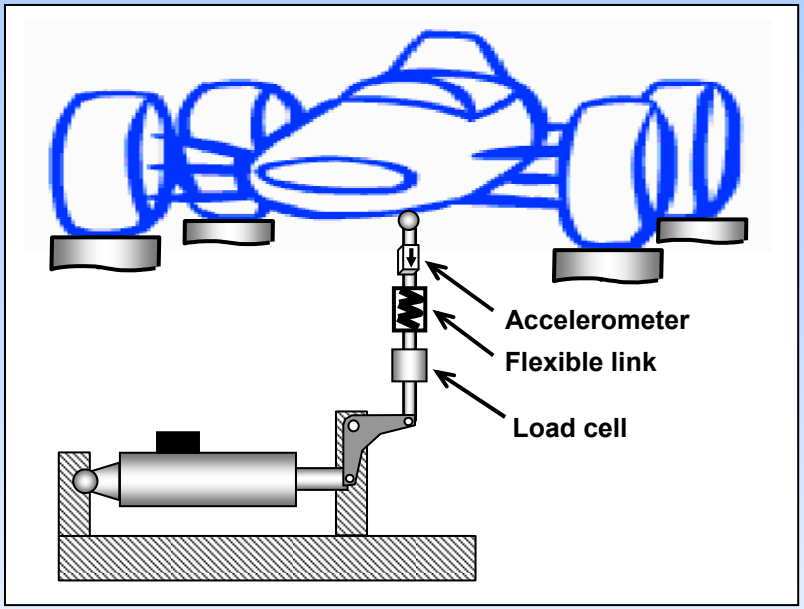
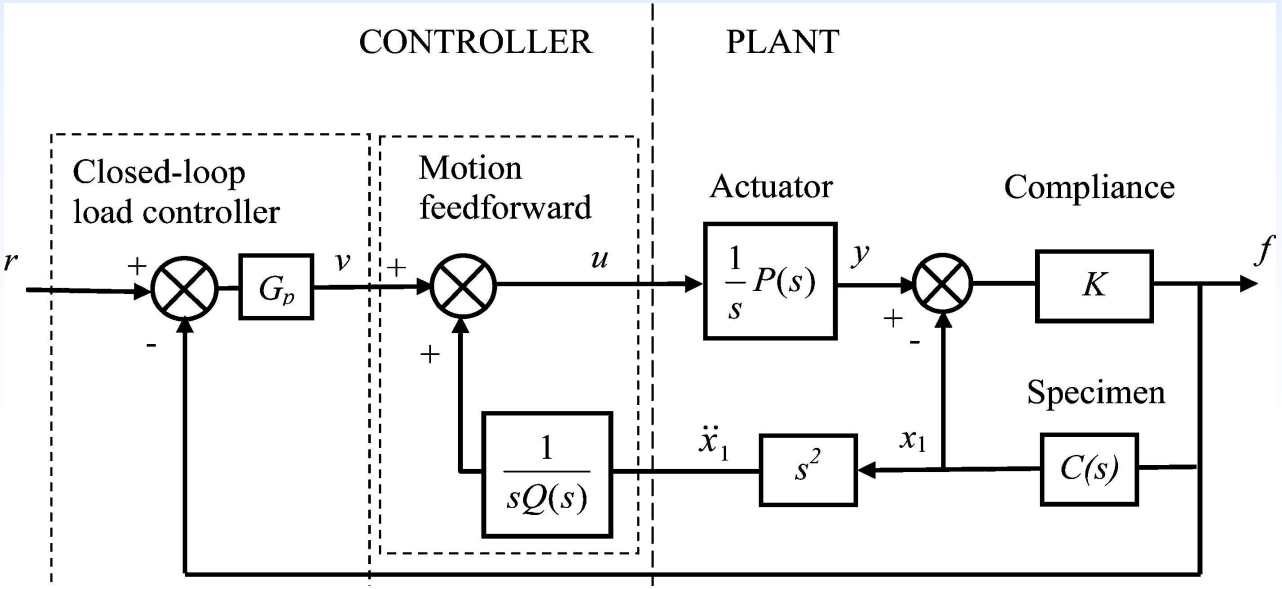
Motion compensated load control

Specimen motion feedforward [5]

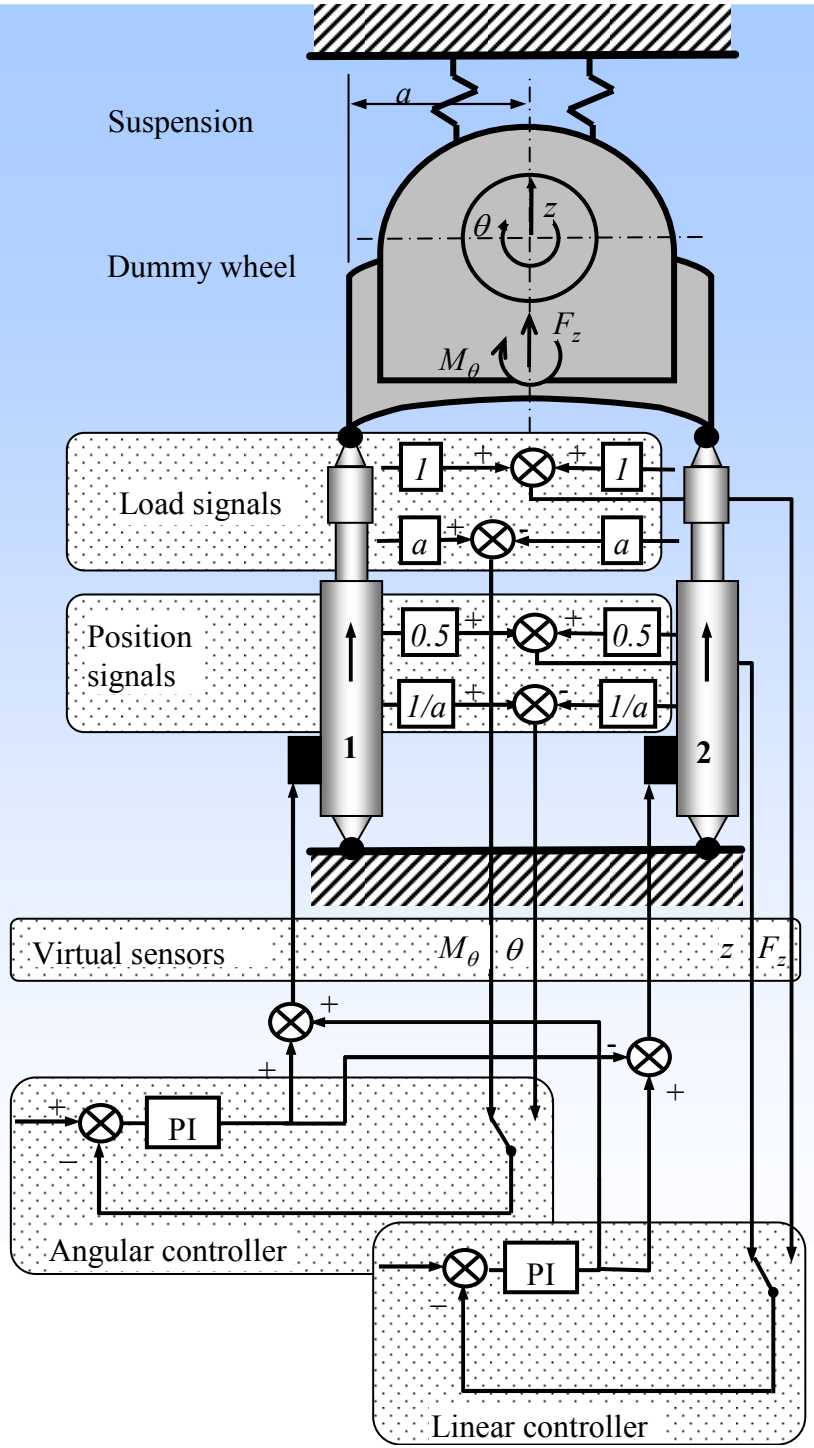


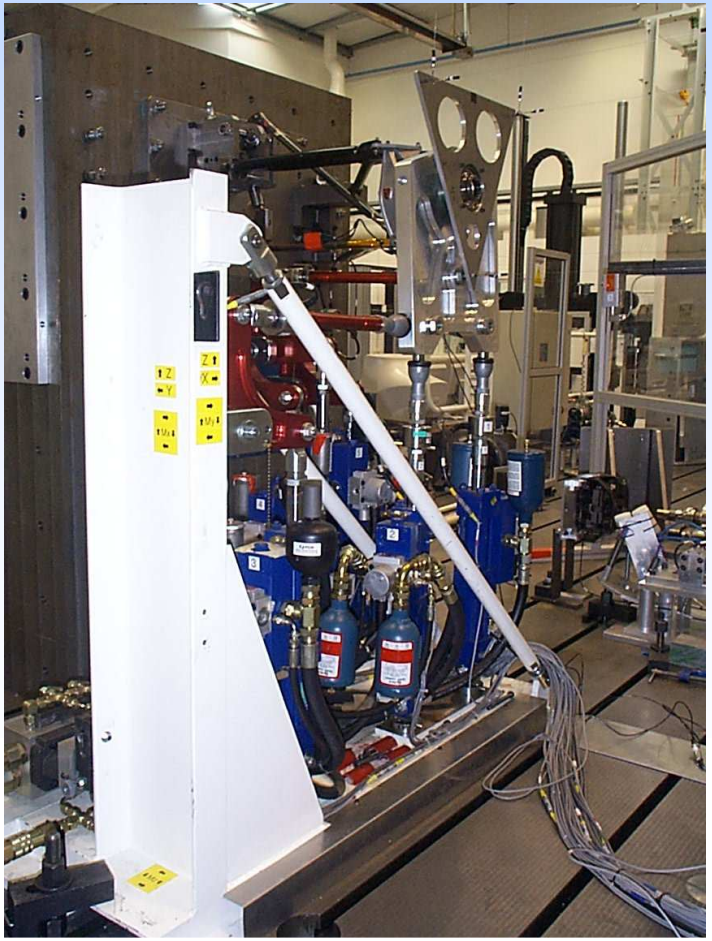




Co-ordinate transformation

e.g. Suspension test rig

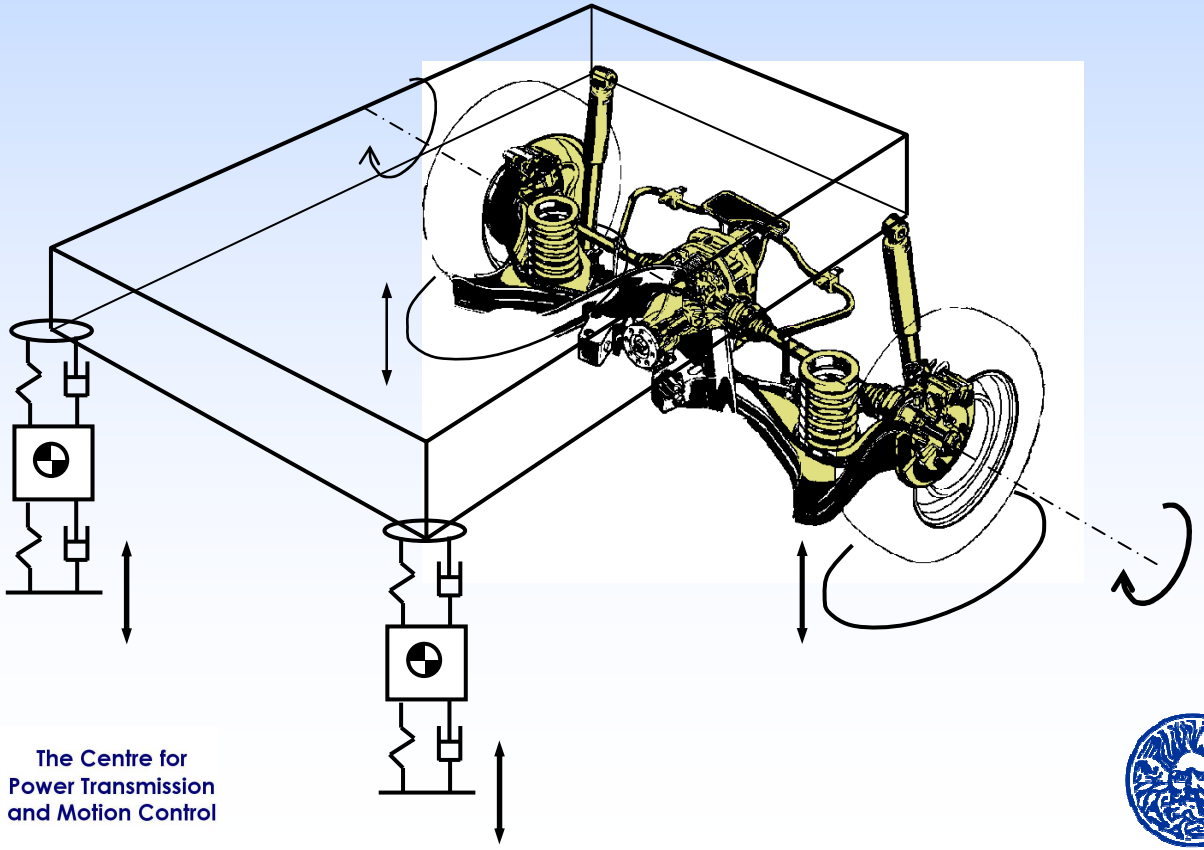




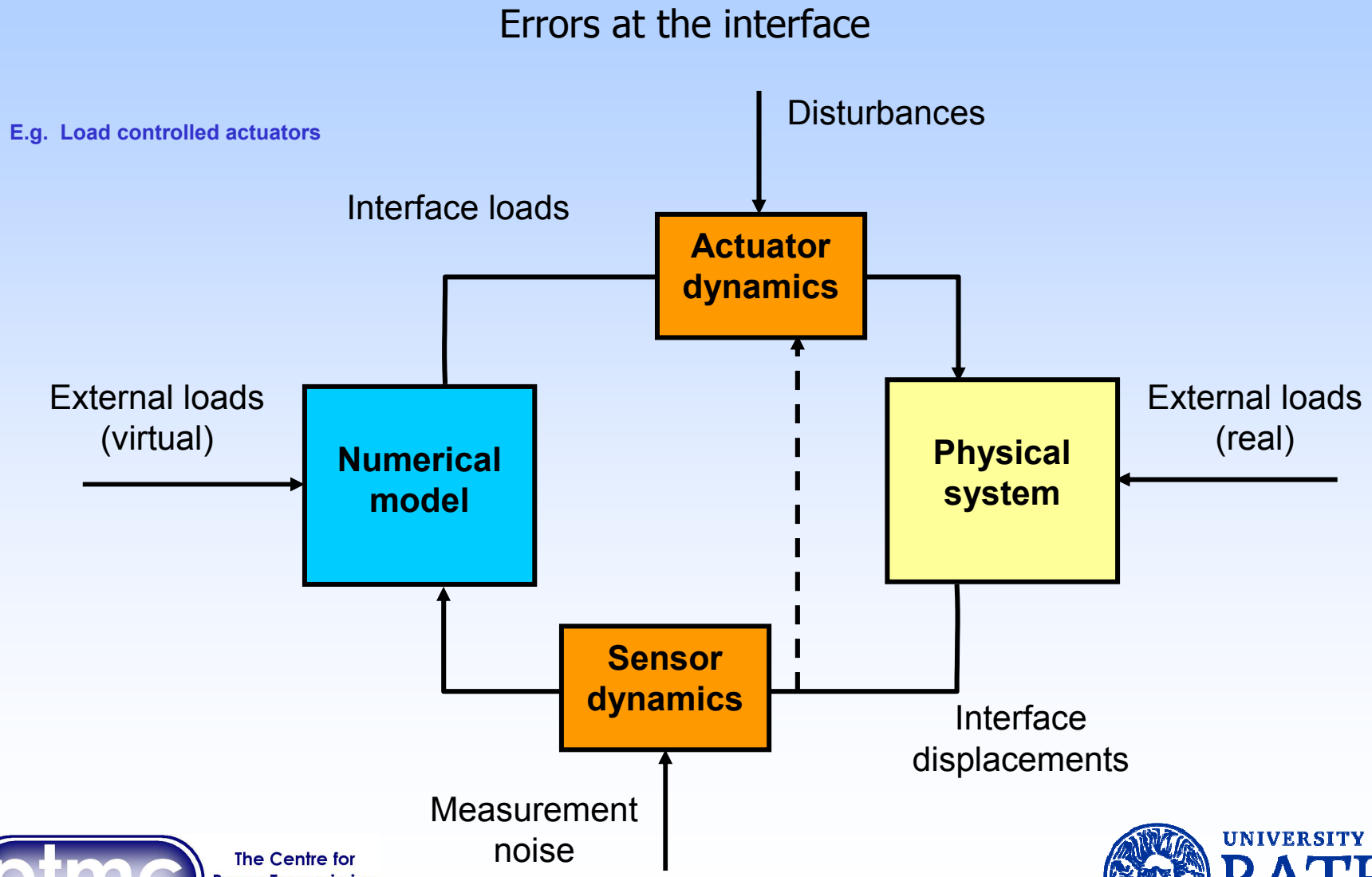
Model-in-the-loop testing [6]

Integration of physical testing with real-time computer simulation

e.g. Real axle and road input linked to virtual chassis



Model-in-the-loop testing



Summary

- Where PI control is inadequate, a variety of techniques are available which:
  - use a modified feedback controller
  - and/or, shape the command signal
- Use of 'outer-loop' methods to shape the command signal based on previous trials (iterative control) has proved very successful over many years.
- Various ways of cross-coupling individual actuator controllers are routinely used in multi-axis rigs.
- Non-linear model-based controllers are now used for specialist applications (both for closed-loop and iterative control).
- Model-in-the-loop testing … many applications but challenging for fast dynamics.

- Refs

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3. Dodds, C J, Plummer A R Laboratory road simulation for full vehicle testing – A Review. *Symposium on International Automotive Technology*, Pune, India, January 2001, 487-494. (SAE 2001-01-0047).
4. Plummer, A R Iterative acceleration control of a hydraulic actuator for vehicle crash simulation *PTMC 2002*, Bath, September 2002, 191-202.
5. Plummer A R Robust Electrohydraulic Force Control. *Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering*. 221 (4). 2007, pp. 717-731.
6. Plummer AR (2006, May). Model-in-the-Loop Testing. *Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering*. 220 (3). pp. 183-199.